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Digital and Sustainable (Twin) Transformations: A Case of SMEs in the European Union

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Abstract: In the European Digital Decade 2030 Policy Program, the following guidelines for European digital transformation are named, which means that more than 90% of small- and medium-sized companies reach at least a basic level of digital intensity. In addition to that, the European Commission pays a lot of attention to implementing the "Green Deal" in order to achieve less environmental impact. ICT SMEs already play a key role in Europe's green and digital transformation, creating technologies that promote sustainability and strengthen Europe's position. The limited and fragmented application of today's digital and sustainable technologies in SMEs is observed at the EU level. The bibliometric literature analytical results show that the number of papers on the digital direction is five times higher than on the sustainable direction topic. The paper seeks to identify directions that could help SMEs to speed up this twin transformation in each EU country. The authors proposed a two-stage methodology, which is used for researching twin transformations in SMEs. According to the methodology, first, the authors analysed the indicators of EU-27 SMEs, representing their activity towards the twin transformation, comparing them among other size classes. The results show that the SME's numbers in the 16 indicators area are worse than the numbers characterizing EU-27 enterprises, having more than ten employees. In addition, a multi-criteria decision making-based assessment framework was constructed to show the progress towards the twin transition. The provided research shows which areas require more attention from SMEs and policy makers responding to the twin transformation objectives.

Keywords: digital; sustainable; transformation; SME; European Union

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1. Introduction

The European Union's (EU) Political Agenda focuses on the prioritized implementation of digital and sustainable transformations (i.e., the twin transition). The successful implementation of the twin transition is particularly important for achieving the UN Sustainable Development (SD) Goals. The 2022 EU Strategic Foresight Report stresses the need to explore the link between these transformations and their ability to strengthen each other in more detail. Implementing the European Commission's Green Deal priorities is essential to achieve the objectives of the Green Deal in the European Union (EU). By now, digital transformation has been implemented with little emphasis on the sustainability aspects. Recent research highlights the importance of green technologies for digital transformation, especially in addressing SD challenges in business. It is noticeable that, while the topic of the twin transition is receiving more attention, research in this area is fragmented, and there is a noticeable lack of research on the topic.

The SME strategy for a sustainable and digital Europe highlights the role of SMEs as the engine of the European economy, making their contribution to the process of change particularly important. Small- and medium-sized enterprises (SMEs) are particularly important for the EU economy, accounting for more than 90% of all enterprises (in total, according to 2023 data, there are 24.3 mln SMEs in the EU). Therefore, it is necessary to provide research in the area to accelerate the digital transformation of SMEs and connect it with SD solutions. The results of this study will provide practical insights to promote the implementation of the twin transition in SMEs. The results obtained from the study and their practical applications will provide a basis for solving the problems of digitalization and sustainability, i.e., environmental issues, and will contribute to increasing the long-term competitiveness of SMEs.

However, there is a lack of knowledge about how the synergy of the twin transformation will affect business and what changes it will bring, considering the current level of digitization [1]. Although both the research on the twin transformation at different levels (micro and macro) and the research on changes in SMEs are gaining strong positions, these issues are rarely explored among researchers. Therefore, the analysis of changes in business resulting from the twin transformation and the assessment of EU SMEs would be a new and significant research area in management studies, and such is the scope of our study. This means that the research on the changes in competitive business under digital and sustainable transformations has not been conducted comprehensively and systematically, and the perspectives of these transformations are unclear. Therefore, analyzing these changes in competitive business advantages resulting from the twin transition and the assessment of SMEs would be a new and significant research area in management studies.

The results of this research will provide practical and social insights to promote the implementation of twin transformations in SMEs. The obtained research results and their practical application will provide a basis for addressing digitization and sustainability issues, as well as environmental and social issues, contributing to the long-term competitiveness enhancement of SMEs in the EU. In today's world, the issues and problems of environmental protection, renewable energy sources, and sustainability are extremely relevant, and the implementation of the project would allow us to achieve higher digitalization and sustainability levels. Thus, this paper responds to the SDGs, the Green Deal, and other related strategies.

For SMEs, changes related to the twin transformation can significantly enhance competitiveness, especially when there is often a lack of knowledge regarding factors influencing these changes and understanding their implications. The research results will be meaningful for policymakers in assessing the readiness of the EU SMEs for twin transformation processes and encouraging the faster implementation of these processes. It is expected that the outcomes of the scientific research will contribute to addressing the challenges posed and strengthen the EU's progress capabilities and commitment to sustainable and digital transformations. Furthermore, the research results are anticipated to serve as a basis for further studies, promoting a smooth and accelerated twin transformation and advancing new management knowledge.

The research fills the gaps in the analysis results of the twin transformation, evident among EU-27 SMEs in terms of speed and develops an assessment framework that helps measure SME progress towards the twin transformation [2].

The authors constructed several research tasks, which were revised during empirical research: (1) to identify main factors that promote and postpone twin transformations; (2) to identify research gaps between SMEs and other sizes of enterprises; (3) to create a research results-based framework that helps to measure SME progress towards the twin transformation.

The paper is composed of six chapters; the first two present the literature review results. The first chapter presents a literature review and provides the results of bibliographic literature analysis. The second chapter focuses on naming factors identified in published papers and influencing SMEs' competitive advantage from the twin transition. The third chapter shows materials and methods. The fourth chapter is dedicated to research on analyzing the twin transformation progress between countries. The fifth chapter is dedicated to a multi-criteria decision making-based assessment framework. Finally, discussions and conclusions are presented. All abbrevations used in the text are mentioned in Appendix D.

2. Literature Review

Implementing digital and sustainable transformations is among the most important topics on the EU political agenda [3]. The successful implementation of these transformations is crucial for achieving the United Nations' sustainable development goals (SDG) [4]. The 2022 EU Strategic Foresight Report emphasizes the linkage between digital and sustainable (twin) transformations and the ability to strengthen each other in more detail [5]. The European Commission Green Deal is a comprehensive strategy aimed at achieving climate neutrality by 2050 through set goals and policies [6]. Until recently, digital transformation was carried out with little focus on sustainability [7]. According to the 2022/2023 European Small and Medium Enterprises (SMEs) Annual Report, about one-third of EU countries lack schemes (tools) to help SMEs adapt to sustainable requirements [8]. There are legitimate questions regarding integrating digital and sustainable transformations and activities focusing on existing businesses' competitive advantage and their clarity and consistency, particularly concerning their adaptation for SMEs [9].

Therefore, to accelerate the digitization of SMEs and connect it to sustainable solutions, it is essential to research the topic and contribute to smoother and faster digitization and SDG in EU countries [10,11]. Recent scientific studies emphasize the importance of digital technologies, particularly in addressing sustainability challenges in business [12,13]. It is observed that considerable attention is paid to the theme of digital and sustainable transformations; research in this area is fragmented, and there is a lack of research on what changes and factors influence them in SMEs' competitive advantage resulting from twin transitions; only a few studies on this topic have been found [14–17]. In those studies, the twin transformation is defined as the double transition that refers to the interplay between digital and green transitions: digital technologies, properly used and managed, can help the economy become (more) resource-efficient, circular, and climate-neutral. Successful and inclusive twin transitions require understanding the synergies between digital and green transitions and implementing proactive and inclusive policies and governance mechanisms [18]. The twin transition therefore requires the involvement of players from all sectors; due to its economic share, the private sector will have a large role to play in implementing the twin transitions [19]. However, maximizing the benefits and minimizing the negative side effects of digitization and greening processes will also require the involvement of the public and civil society sectors [20].

The research on the competitive approach and its changes in SMEs is gaining strong positions among foreign and Lithuanian researchers. Rao et al. (2023) [21] define "business competitiveness as the ability of a company to sustainably fulfill its dual purpose, i.e., meet customer requirements and make a profit, which guarantees long-term business development". This opportunity can be realized by offering goods and services that customers value more than competitors. Sabaityte et al. (2022) studied the development of e-businesses as a sustainable competitive advantage [22], and Gao et al. (2022) explored businesses' abilities to absorb innovations [23]. The growing interest in the topic of twin transformations is evident among both researchers and practitioners. Recent scientific studies emphasize the importance of green digital technologies, addressing sustainability challenges in business [24–26]. Analyzing the latest scientific research, it is observed that considerable attention is paid to the theme of digital and sustainable transformations [12,13,27]. While there are about 1400 articles on twin transformations in Clarivate Analytics, research in this area is fragmented. The studies only partially examine SMEs, focusing on creating taxonomies in different industries, and they pay relatively little attention to SME changes. An analysis of separate topics related to the research theme (digitization, sustainable development, business changes) reveals that recent scientific research in this field is oriented toward evaluating the impact of digitization on sustainability (environmental, social dimensions, etc.) [10,25,26,28–31], assessing the transformation possibilities [16], and the different types of organizations [32] resulting from digitization. The evolution to sustainability-oriented businesses [33], the concept of change management in the context of sustainability and digital changes, and the relationship between these variables have been examined [34]. Research has been conducted on changes in business resulting from digitization [35–38], as well as the business changes oriented towards sustainability [39,40].

Digital and sustainable transformations enable SMEs to reduce their environmental footprint [41]. For example, the implementation of digital solutions, such as cloud computing or teleworking, will allow SMEs to reduce their energy consumption and greenhouse gas emissions. Sustainable changes, such as reducing waste, recycling, or using renewable energy sources, can also include other environmentally friendly practices [42].

Following the literature review, the authors could define several perspectives important for successful twin transformations.

From an organizational change perspective, managing and implementing change in organizations is essential [9]. SMEs can apply change management principles and strategies to plan and implement digital and sustainable transformations effectively, considering factors such as communication, training, and organizational culture [43]. Digital and sustainable transformations often require a change in organizational culture that encourages new forms of work and new sustainability practices [44]. SMEs engaged in digital and sustainable transformations often need significant organizational changes in order to adapt to new technologies, practices, and initiatives, which requires effective organizational change management. Organization change theory provides planning guidance, implementing, and monitoring SMEs' digital and sustainable transformations [45]. These include assessing the need for change, developing a change management plan, communicating with stakeholders, and managing resistance to change [46]. Digital and sustainable transformations are ongoing processes that must be continuously improved and adapted. SMEs have continuously learned and developed mechanisms for feedback, evaluation, and adaptation [47]. This will enable SMEs to cope with the complexity of change and continuously improve their digital and sustainable know-how [48]. This helps them solve organizational challenges, hire employees, and create an environment conducive to successful recruitment and long-term impact.

Orienting internal resources and capabilities from a resource perspective is important to gain a competitive advantage [49]. SMEs can identify their assets and capabilities that can be used as part of dual transformation initiatives [50], such as skilled labor, data assets, or technology infrastructure [51]. By effectively identifying and using these resources, SMEs can improve their digital capabilities and competitiveness in the market [50]. Valuable and abundant resources can create a long-term competitive advantage [51]. In a digital and sustainable environment, SMEs can use their unique digital and durable assets in order to stand out from their competitors [52]. For example, SMEs implementing innovative digital solutions or sustainable practices can become leaders in relevant fields. Importantly, resource bands rely on resource pooling and integrating resources to create value. Through digital and sustainable transformations, SMEs can strategically combine their digital and sustainable capabilities to drive change, increase operational efficiency, and develop new business models [53]. Resources and capabilities could be important to implement twin transformations effectively.

From a solution perspective, it should be easy to use and support a user-friendly approach, which is key for SMEs to make changes for workers and stakeholders [54]. Such qualities as easy-to-use and user-friendly influence the application of environment-oriented digital technologies in SMEs [55,56]. SMEs can understand the specificities of the early adopters of sustainable practices and develop strategies to promote their wider use through workers, suppliers, and other stakeholders [57]. SMEs can identify individuals or stakeholders who can support adopting environment-oriented digital technologies, facilitate knowledge sharing, and encourage other SMEs to benefit from such solutions [58]. SMEs can gain valuable knowledge on recognizing and disseminating digital and sustainable change. This understanding can contribute to SMEs' strategies, successful implementations, and positive organizational changes [59].

From a competitive advantage-gaining perspective, digital and sustainable transformations will help SMEs ensure that their initiatives contribute to long-term success [60]. While digital and sustainable transformations may require an initial investment, they can bring long-term economic benefits to SMEs [61]. Digital technologies can improve operational efficiency, streamline processes, and increase productivity, resulting in cost savings and increased revenue. The twin transformation makes the most of resources and reduces brand and reputation risks, which can positively affect the result. SMEs can align their initiatives by considering the environmental and economic aspects of the digital and sustainable transition [62]. This approach helps SMEs to create value for their businesses, society, and the environment, promoting a more sustainable and responsible approach to growth and development. SME efforts toward digital and sustainable transformations ensure social responsibility requirements are met [63].

By understanding these perspectives, SMEs can develop strategies that reflect their specific organizational environment and goals.

In summary, the factors are highlighted as follows:

(1) SME role. SMEs should have objectives to be digital and sustainable, and to follow strategic plans and policies that guarantee successful a twin transition, including proper communication, resources, training, and a change of organizational culture.
(2) Knowledge role. Knowledge is required to understand and successfully implement twin transformation initiatives, with training for end-users to develop the skills and capabilities needed to work with new digital and sustainable approaches and reach practical effects.
(3) Solution role. Companies have to support research and innovation activities that support the development of new solutions responding to SME needs, which are easy to use and user-friendly, that help to achieve a twin transformation.

Talking about the solution role, it was detected that some Industry 4.0 technologies are implemented to achieve more sustainable business, reduce waste, and increase efficiency [64].

Bibliometric Research on the Topic of Twin Transformations in SMEs

The authors performed bibliometrical research in three steps by identifying clusters with interlinked topics. The first step includes the revision of the studies on transformation topics. The second step covers the review of studies writing about the twin transition. The third step is dedicated to revising the SME study area.

All three steps followed such methodological guidelines as follows:

- The VOSviewer program is used for the analysis of the articles published during 2023 in the Web of Science database;
- Bibliographical coupling analysis helps to identify the co-linked words and clusters;
- The map for twin transformations in SMEs is established from revised studies based on the co-occurrences of main words in the titles of studies.

After researching the keywords "Digital transformation", "twin", and "SME" to search for articles, the authors of this paper, with VOSviewer (1.6.20 version), created bibliographic maps and formed the clusters mentioned above. The authors included all open-source articles that VOSviewer retrieved. For the retrieval of publications with VOSviewer, the authors used the year 2023 to limit the number of retrieved papers. All papers that were published during the year 2023 were included. During the clusters' construction, the number of papers did not exceed 50,000 publications per retrieval iteration [65].

VOSviewer uses VOS mapping technology, which investigates "similarities". Van Eck et al. (2010) discuss this mapping technique in detail [66]. By default, VOSviewer assigns nodes to cluster networks. A cluster is a group of nodes that are tightly coupled to it. Each node in the network is connected directly to the cluster. The solution parameter determines the number of clusters. The higher the value of this parameter, the greater the number of clusters. In the bibliometric network visualization, VOSviewer uses colors to represent the cluster to which the node is assigned. Waltman, Van Eck, and Noyons (2010) discuss the clustering technique used by VOSviewer [67]. This technology requires an intelligent local traffic algorithm, which was introduced by Waltman and Van Eck (2013) [68].

The formed bibliographic map (presented in Figure 1) uses papers with some characterizing attributes. First, the circles on the map have colors, presenting different clusters and identifying closely linked keywords. The lines on the map indicate the links among keywords and show the strength of such links. The distances between words show the strength of connections.

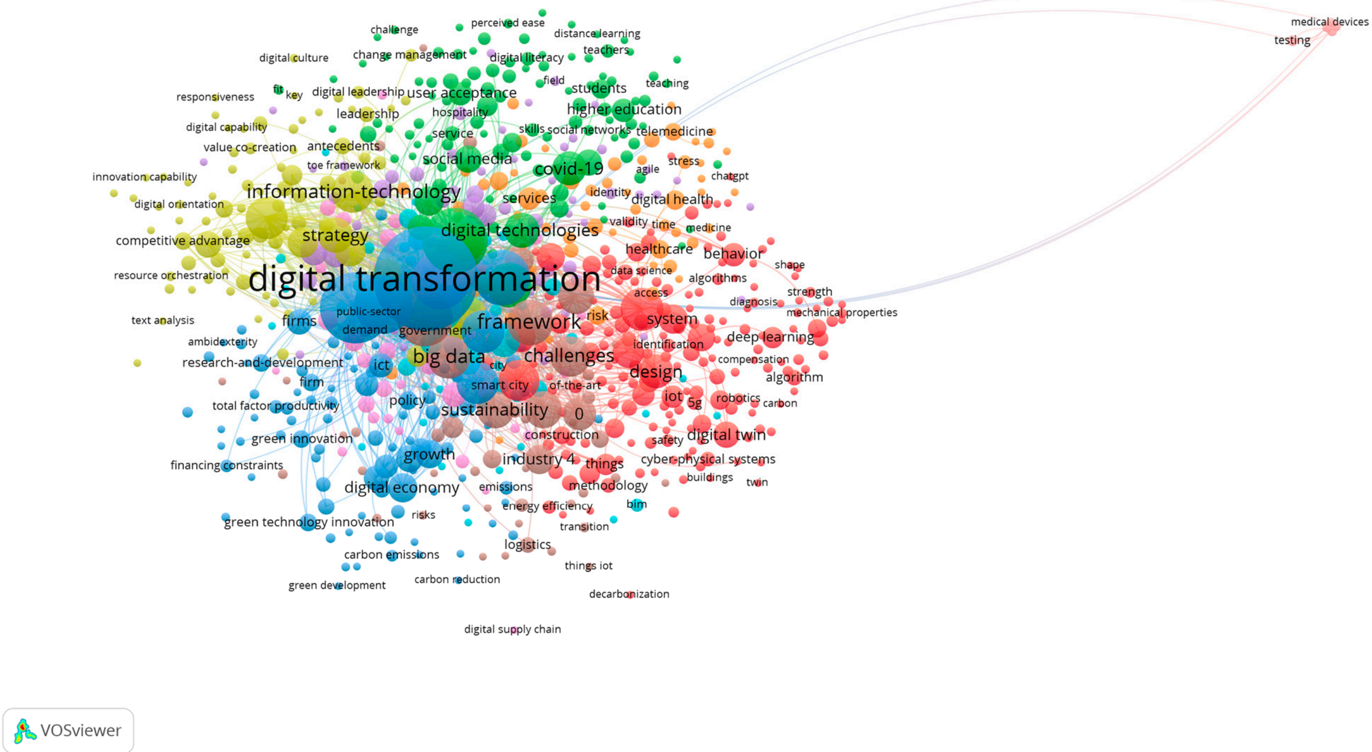

Figure 1. The cluster formed on the topic of "Digital transformation".

The results of the bibliometric research are demonstrated below by presenting three clusters, which summarize the results of words used for clusterization.

For the presentation, the authors took just the results on concrete clusters, not all the clusters formed by using three keywords mentioned above: "Transformation", "twin", and "SME". The first cluster's keywords, "digital transformation" and "digital technology", have 655 and 529 links, respectively. Other words such as "sustainable development" have 288 links, "sustainable development goals", "SME", and "SMEs" have 50 links. All these keywords belong to the same cluster and are presented in Figure 1. This keyword is closely linked to the cluster and contains extensive literature on digitalization in SMEs and in the context of sustainability.

The second cluster focuses on the twin transition (Figure 2), and the keywords "digital" and "sustainability" have 23 and 182 links, respectively. In addition, "sustainable development" has 35 links, "twin transition" has 45 links, and "digital transformation" has just 75 links. All these keywords belong to the same cluster. However, the papers are not linked with the SME context. This keyword emphasizes the grouping of sustainable concepts with digital concepts. Also, the link to the SDGs suggests that some of the literature on the topic may focus on aligning the transformation with broader global goals, but the topic is not dedicated to SMEs' needs.

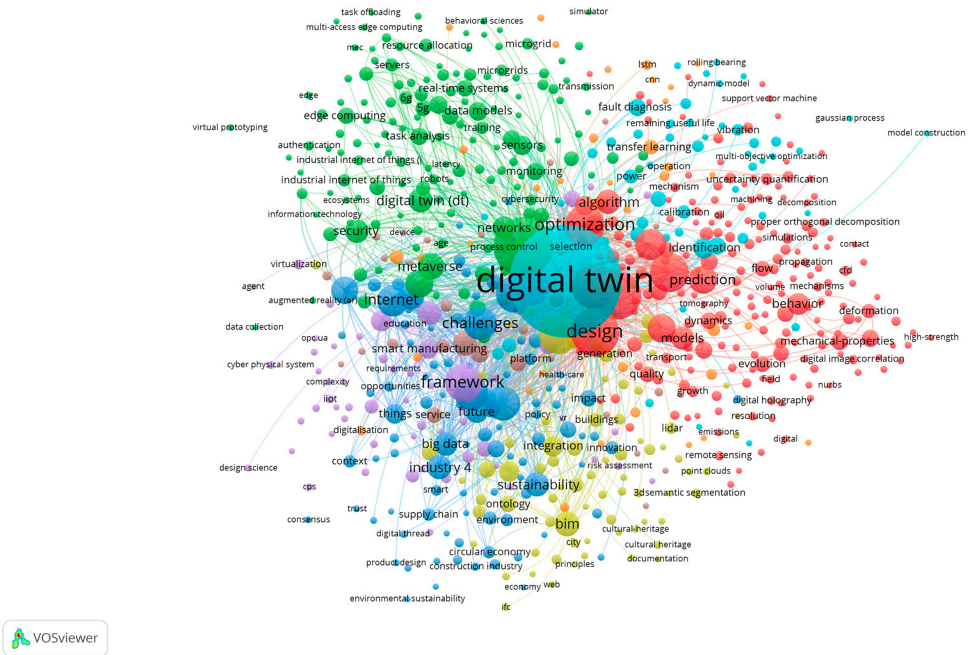

Figure 2. The cluster formed on the topic of "twin".

From the third cluster focusing on "SME" matters (Figure 3), the keyword "digital transformation" has just 135 links. However, the keyword "SME" belongs to a different cluster. When grouped, these keywords represent the average ratio compared to keywords related to digitalization. This suggests that the literature explores where SMEs face a digital transition, but this may not be the most important thing.

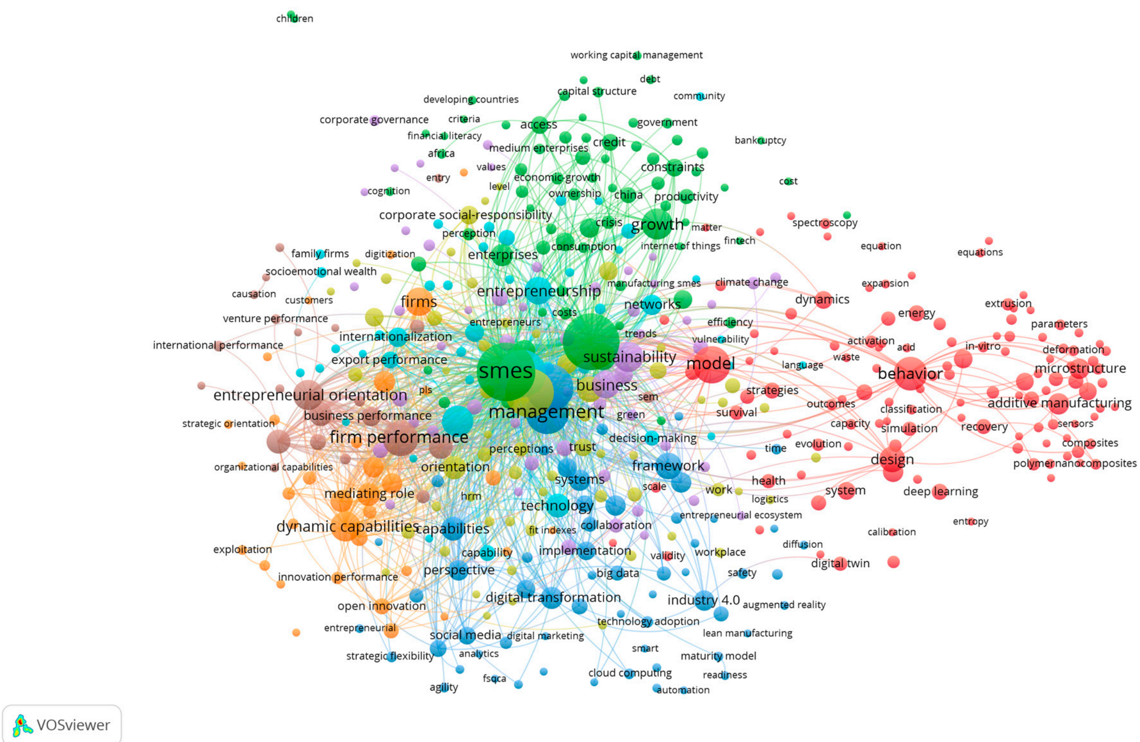

Figure 3. The cluster formed on the topic of "SME".

The results of the study show that there are no papers that cover twin transformations in SMEs. There is an evident research gap, and the topic still lacks research that can fill this gap.

The first cluster focuses on digitalization and its integration into sustainable development, with a particular focus on SMEs.

The second cluster focuses on partnering for digitalization and sustainability in a more sustainable way but does not seem to be directly related to SMEs.

The third cluster concerns SMEs, but the number of links related to digitalization is smaller than the number of references to the main set of digital transformation actions.

3. Factors That Influence SMEs' Competitive Advantage Resulting from Twin Transitions

Some factors influence SMEs' competitive advantage resulting from twin transitions. These factors and their relationship to the papers are described below.

The set of factors is named for a revising competitive advantage resulting from twin transitions. Therefore, according to the literature, the set consists of the following factors:

(a) The number of SMEs that became digital and sustainable [69];
(b) The resource productivity level reached during the twin transformation [70];
(c) The market share gained for selling products produced using technologies that are friendly to the environment [71];
(d) The initial investment [72];
(e) The technical complexity [73];
(f) The number of digital and sustainable technologies applied by SMEs [74,75].

The first factor is the number of SMEs that have become digital and sustainable. The use of digital and sustainable practices in companies can be analyzed using the Rogers innovation adoption curve. The curve, proposed by Rogers, describes the process by which companies embrace innovation over time. This model divides users into five segments:

- Innovators (2.5%). Innovative companies are the first to introduce digital and sustainable practices. They often have a high appetite for risks and are willing to experiment with new technologies and sustainable initiatives. At this stage, the first users of digital technologies can invest in advanced technologies, such as artificial intelligence, the Internet of Things, or blockchain, to simplify their work and strengthen their sustainability efforts.
- Early adopters (13.5%). Early adopters closely monitor innovators. They monitor the successes and failures of innovators and take more calculated risks. These companies can integrate digital solutions such as cloud services, data analytics, and early sustainable practices into their business models.
- Early majority (34%). As digital and sustainable practices become more and more tested, most companies begin embracing them. These companies avoid more risks and require proof of the benefits of such conversions.
- The late majority (34%). Late majority companies are characterized by great skepticism and a refusal to change. Digital and sustainable practices can only be introduced if they become a universally accepted norm or are forced to be applied by the market. Implementation at this stage may include upgrading existing systems, optimizing supply chains for sustainability, and aligning with the industry environmental standards.
- Laggards (16%). Laggards are the latest companies to adopt digital and sustainable practices. They resist change and can only do so if they face serious problems or when their survival is threatened. At this stage, companies can implement key digital assets and sustainable measures in order to meet regulatory and customer needs.

At each stage of the Rogers curve, the number of companies varies depending on industry, geographic location, and other factors. However, over time, there is a general trend for digital and sustainable practices to become more common as technology matures, awareness increases, and market pressures likewise increase. Companies successfully move around this curve and strive for long-term competitiveness and sustainability in an ever-changing business environment.

The second factor is the resource productivity level reached during the twin transformation. Resource productivity in digital and sustainable transformations refers to the efficiency with which companies use resources in their operations, while reducing their environmental impact. Integrating digital technologies and sustainable development practices can significantly increase resource productivity. Digital technologies such as automation and robotics optimize production processes, reduce waste, and increase resource efficiency. Automated systems can accurately perform tasks, minimizing errors and resource consumption. The IoT enables the real-time monitoring and management of devices and processes, as well as improving feature utilization by providing insights into power consumption, device performance, and supply chain efficiency. Advanced data analytics help organizations analyze large amounts of data to identify inefficiencies and opportunities in order to optimize resources. Applying sustainable management principles includes developing recyclable products and implementing strategies for reusing, recovering, and recycling materials. This reduces resource consumption and waste. A sustainable transition often requires renewable energy sources, energy-efficient technologies, and advanced energy management systems. This reduces the impact of energy consumption on the environment. Sustainable business practices focus on reducing waste, reducing emissions of CO_2, and ensuring ethical sourcing. This helps in the preservation of resources along the entire value chain.

The third factor is the market share gained for selling products produced using environmentally friendly technologies. The market share in the sale of products made with green technologies shows that consumers increasingly opt for sustainable and environmentally friendly options. When companies adopt and promote technologies that reduce the environmental impact of their production processes, they often achieve positive results in terms of market share.

Digital and sustainable transformation brings with it many benefits but can also lead to challenges and negative factors. It is important to identify and address these issues in order to get a balanced picture of the effects of these changes. Here are some of the disadvantages that can arise after a digital and sustainable transformation:

The initial investment factor is important. The initial cost of implementing digital technology and sustainable practices can be high. This financial burden can be complex, especially for small- and medium-sized enterprises (SMEs) with limited resources.

In addition, the technical complexity factor is evident. Integrating new digital systems into existing infrastructures can be difficult and disruptive. Ensuring seamless interoperability and resolving technical issues can increase resources and require additional investment.

For the last factor, it is important not only to revise the number of enterprises with digital and sustainable practices, but also the number of digital and sustainable technologies applied by SMEs. Most EU-27 SMEs recorded low (34%) or very low (45%) digital intensity levels because they applied only three or even up to six technologies. Only 3% of the EU SMEs reached a very high level of digital intensity and did so by applying twelve technologies, while 18% reached a high level in applying nine technologies [75].

Below (see Table 1), the direction of the factor, which is positive or negative (in column 2), is defined.

Table 1. The direction of factors.

Factors	**Positive/Negative**
(a) Number of SMEs that became digital and sustainable	Positive
(b) Resource productivity level reached during twin transformations	Positive
(c) Market share gained for selling products produced using technologies that are friendly to the environment	Positive
(d) Initial investment	Negative
(e) Technical complexity	Negative
(f) The number of digital and sustainable technologies applied by SMEs	Positive

Source: created by the authors.

Other indirect factors could also occur during twin transformations, such as educating consumers about the environmental benefits of products manufactured using eco-friendly technologies, which can influence purchasing decisions and increase market share.

In summary, using environment-orientated digital technologies can lead to cost savings over time and increase the competitiveness of businesses. This profitability can be passed on to consumers at competitive prices, further increasing the market share.

The factors named in this section will be further used in the paper to develop a multi-criteria decision making-based framework.

4. Materials and Methods

The authors analyzed the scientific literature, reviewing the quantitative methods used in the research of other authors. Authors use different methods to research the topic, therefore, they analyze the most common methods following the paper published on the digitalization topic by Burinskiene et al. (2022) [76].

Table 2 summarizes and provides a revision of the studies. The authors found that in the research works of other scientists, some methods are occasionally mentioned among the quantitative methods listed above. In the meantime, the AHP method allows us to identify variables, which then help to define the situation.

Table 2. The hierarchy of quantitative methods and models for researching twin transformations in SMEs.

Model	Modeling Technique	Method of Solution	Sources
Mathematical programming methods	Single objective	Linear programming	[77]
	Multi objective	Multi-objective integer linear programming	[78]
		Non-linear analysis	[79]
	Time series	Multiple regression	[74,80]
Causal models	Causality identification	Causal effect modeling	[81]
		Diagram of causal systems	[82]
Heuristic methods	Heuristic approach	Fuzzy logic	[83]
	Metaheuristic	Genetic Algorithm	[84]
Analytical models	Multiple-criteria decision supporting methods	AHP	[85]
		COPRAS	[86]
		DEMATEL	[87]
		TOPSIS	[88]
	Systematic models	Delphi method	[89]
		Network model	[90]
Artificial intelligence methods	Language models	Large language models	-

Table 2 shows that the most popular methods are multiple regression methods. These methods are mentioned by Mubarak et al. (2019) and Teng et al. (2022), who write about the impact of digital transformation on SMEs' business performance, seeking to investigate the relationship between digital transformation and the performance of SMEs [74,80].

Some words about papers applying the methods are mentioned in Table 2. Yin et al. (2022) mention the linear programming method, enhancing the digital innovations for sustainable transformation, which covers the perception of innovations and their performance, helping to encourage greener activities [77]. Spaltini et al. (2021) use multi-objective integer linear programming to develop a quantitative framework for Industry 4.0-enabled circularity [78]. Arranz et al. (2023) present a non-linear analysis showing digitalization dynamics in SMEs approaching higher levels of sustainability [79]. El Hilali et al. (2020)

suggest a causal effect modeling technique for reaching sustainability during a digital transformation [81]. Morozko et al. (2022) apply the fuzzy logic in SMEs [83]. Jomthanachai et al. (2020) discuss the application of genetic algorithms for investigating resource management with IT tools at the firm level [84]. Among multi-criteria methods, Lacurezeanu et al. (2021) apply AHP for integrated management solution development, seeking more sustainable SMEs [85]. Sriram et al. (2021) promote COPRAS to analyze the readiness for Industry 4.0 implementation in SME cases [86]. Kumar et al. (2022) show fuzzy DEMATEL analysis to strengthen the social performance of SMEs under digitalization [87]. Nichifor et al. (2021) show the TOPSIS application for researching how SMEs become more sustainable [88]. Petani et al. (2023) use the Delphi method to study what sustainable digital maturity will (and should) look like in business ecosystems and do so via identifying the best practices, barriers, and regulations of digital transformation [89]. Sassanelli et al. (2022) talk about the network model for supporting the digital transformation of small and medium enterprises [90].

Table 2 shows that the COPRAS method could be suitable for further research as it was previously applied to analyze the readiness of SMEs for the implementation of Industry 4.0. The COPRAS method for an application always involves positive and negative criteria, as already identified in Section 2.

In this paper, the authors apply statistical analysis and the multi-criteria decision-making method COPRAS to research the differences among the countries. Using the multi-criteria decision-making method, the authors will develop a framework that integrates the COPRAS method. The framework will integrate the factors named under Section 2.

The topic of this article falls into the triangle of such keywords: twin, transformation, and SME, which are placed on the vertexes of the triangle, and the single phrase unifying all other keywords is placed inside the triangle—digital and sustainable (Figure 4).

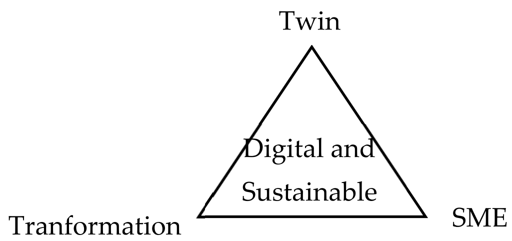

Figure 4. Triangle of research keywords.

Following Figure 4, transformation can be viewed as shifting the business system into a new stage, which creates extra added value. Following other keywords, we could say that digitalization means using digital technologies in order to reach a higher competitive advantage in company business processes. The same goes for sustainability. Sustainability could be referring to economic, environmental, and social maintenance. In this research, the authors focus on environmental sustainability, which meets the needs of nature, aiding in the preservation of natural resources for future societies.

The "twin" keyword unifies digital and sustainable terms, which are in the middle of the triangle. Twin is sometimes also called duality [91]. On the left side of the triangle, the keyword "transformation" presents the change situation, seeking to digitalize activities and reach sustainability. In 2018, Goerzig et al. (2018) [92] presented the process of an enterprise's transformation, where the results of a transformation are called a conscious change in business performance. On the right side of the triangle is a keyword representing SME, which shows that research is dedicated to such types of private enterprises.

The authors will perform research in such stages as follows (according Table 3):

1. First, the progress of the twin transformation in SMEs between countries is investigated by using the indicators of the application of environment-oriented digital technologies in all EU-27 sectors, except the financial activities sector, using Eurostat data.

2. Second, the authors provide the multi-criteria decision-making framework, using the background of the COPRAS method to assess SMEs seeking to define the status of twin transformations.

Table 3. Several stages of methodology for researching twin transformations in SMEs.

Stages	Approach toward the Twin Transition in SMEs	Technique to Achieve Results	Assessment of Compliance with the Requirements Important for the Transition
1st-stage			
The identification of the status of twin transformations in SMEs	The identification of current status and achievements	Data analysis and benchmarking with other enterprises of other sizes and among countries	Achievement in using green ICT practices, achieving environment-oriented performance, integrating sustainability into company strategy
2nd-stage			
Measuring the performance of twin transformations in SMEs	The construction of multi-criteria decision making-based assessment framework	COPRAS, the ranking of factors by experts, the coefficient of concordance calculation for the revision of the consistency of experts' judgments	The identification of the means necessary for twin transformations in SMEs development, which policymakers could then apply

The research results of the first stage are presented in the fourth chapter, and the results of the second stage are provided in the fifth chapter.

The research results are presented below.

5. Statistical Analysis on Twin Transformation Progress in SMEs between Countries

Eurostat (2023) provides information on various aspects of information and communication technologies and the environment [65]. The analysis of this data will provide insight into the relationship between ICT, environmental practices, and the digital and sustainable transformation of SMEs in the EU. Here are some of the main areas of the association's activities:

- Eurostat data on the use of ICT by SMEs in the EU can provide an overall picture of the level of digitalization. The high penetration of information and communication technologies may signal a stronger trend towards the sustainable activities of SMEs.
- Eurostat data on the use of green or green ICT practices show how SMEs integrate sustainability into their digital strategies. This includes measures about the adoption of environmentally friendly technologies.
- Eurostat's monitoring of data on environmental reporting practices in SMEs that are active in the environmental sector can demonstrate the degree of ICT integration and sustainability. Digital tools play an important role in collecting, analyzing, and communicating information about an organization's environmental performance.

Understanding the link between Eurostat ICT data and the digital and sustainable transformation of SMEs in the European Union requires an in-depth analysis of different aspects of digitalization and sustainability. Researchers and policymakers can use this knowledge to develop strategies in order to promote the coherent integration of ICT and sustainable practices in the EU SME sector.

The authors analyzed 22 indicators collected from the Eurostat database about European Union SMEs, representing the implementation of solutions during 2022 and the progress of the twin transformation.

The indicators presented in Figure 5 show that the best value is for the indicator presenting the disposal of unused ICT equipment. This is evident in all types of enterprises according to their size, based on the number of employees.

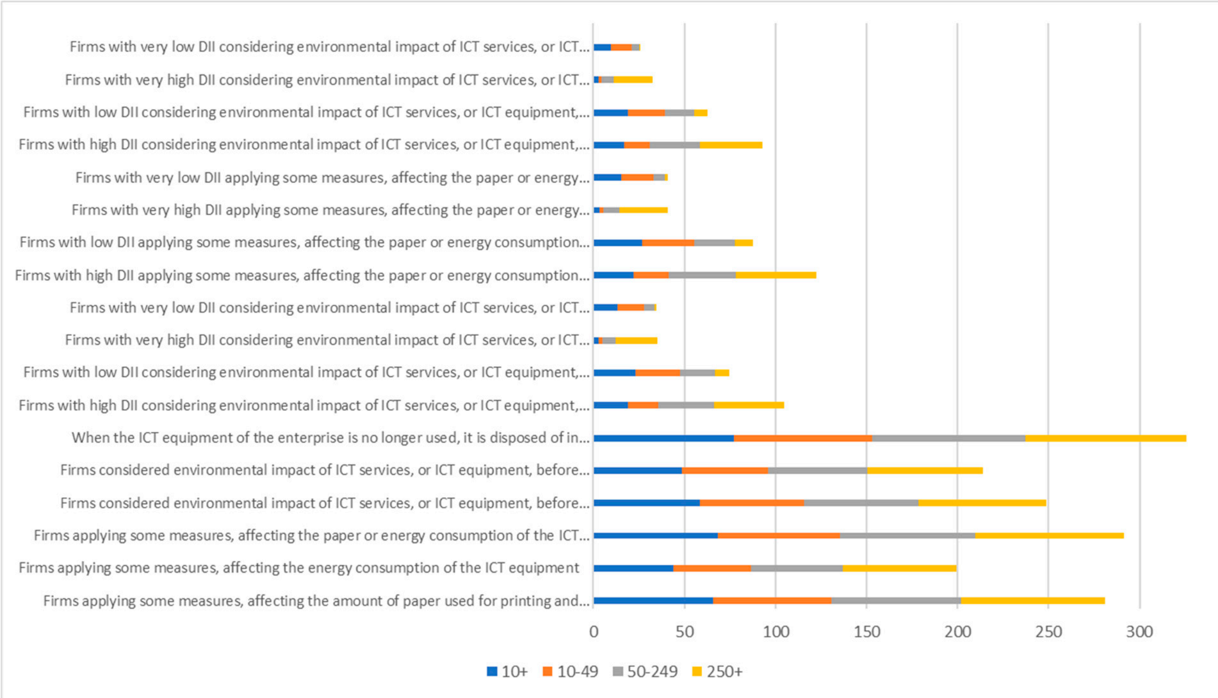

Figure 5. The application of environment-oriented digital technologies in the EU-27 enterprises in 2022 (X axe—the values of indicators, Y axe—the indicators collected from the Eurostat database about European Union SMEs. In Figure 5, DII means the digital intensity index).

The results of SMEs were compared for eighteen positive indicators with other enterprises of other sizes, and four of them are negative indicators, which means that the higher the value, the worse the situation is. The authors created the map (see Figure 6), representing the application of environment-oriented digital technologies by countries, representing average values of eighteen positive indicators.

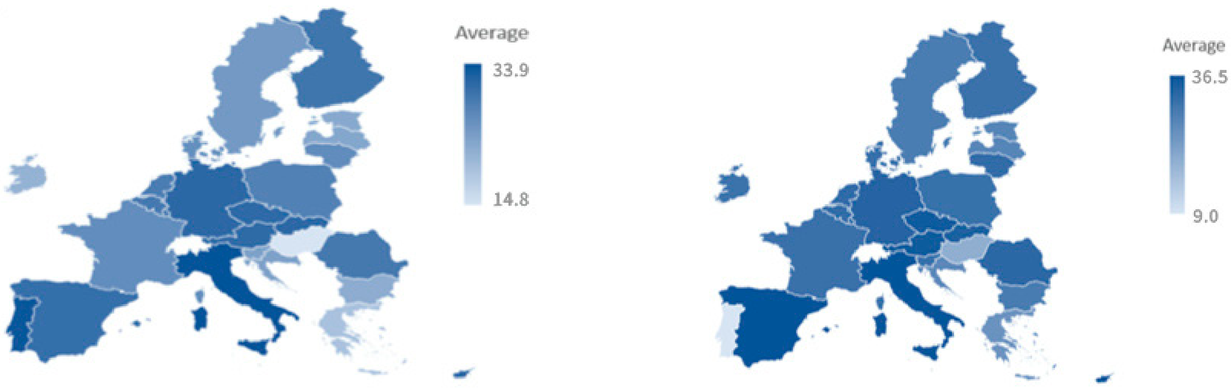

Figure 6. The application of environment-oriented digital technologies in the EU-27 countries in 2022 (on the left side—small firms, on the right side—medium firms).

The results show that the SME's numbers in the twelve indicators area are worse than the numbers characterizing EU-27 enterprises having more than ten employees (in particular, except for six indicators representing the following: (1) Firms with low DII, considering the environmental impact of ICT services, or ICT equipment, before selecting them; (2) Firms with very low DII, considering the environmental impact of ICT services, or ICT equipment, before selecting them; (3) Firms with low DII, applying some measures, affecting the paper or energy consumption of the ICT equipment; (4) Firms with very low DII, applying some measures, affecting the paper or energy consumption of the ICT equipment; (5) Firms with low DII, considering the environmental impact of ICT services, or ICT equipment, before selecting them, and applying some measures, affecting the paper or energy consumption of the ICT equipment; (6) Firms with very low DII, considering the environmental impact of ICT services, or ICT equipment, before selecting them, and applying some measures, affecting the paper or energy consumption of the ICT equipment.

Using statistical data, the authors formed two maps following average values of 18 positive indicators. The countries' results show that small enterprises with 10 to 49 employees outperform the medium-sized enterprises with 50 to 249 employees in Portugal, where small enterprises are more active than medium-sized enterprises (according to Figure 6). The highest value is of indicator enterprises applying some measures, affecting the ICT equipment's paper or energy consumption—85.4 in Austrian SMEs. However, the highest value of indicators indicating enterprises disposing of ICT equipment that is no longer used in electronic waste collection/recycling is in Finland—90.9.

There are four negative indicators (mentioned above): Firms applying no measures affecting the amount of paper used for printing and copying; Firms applying no measures affecting the energy consumption of the ICT equipment; Firms that did not consider the environmental impact of ICT services or ICT equipment before selecting them; Firms where the ICT equipment of the enterprise is no longer used, and they dispose of it in electronic waste collection/recycling. The highest values of these negative indicators are evident in Hungary (first and second indicators), Greece (third indicator), and Bulgaria (fourth indicator).

6. Multi-Criteria Decision Making-Based Assessment Framework

Based on the factors that influence SMEs' competitive advantages resulting from twin transformations, the authors form the assessment framework with the background of the COPRAS method.

The multi-criteria decision evaluation system is a structural method used to evaluate alternatives and prioritize them based on various criteria (using Table 1). The following criteria have been established for assessing the digital and sustainable transformations of SMEs with both a positive and negative impact:

(1) The number of SMEs that became digital and sustainable (positive).

This criterion reflects how SMEs have successfully adopted digital and sustainable practices. This most positively impacts the ecosystem and brings economic, social, and environmental benefits with it.

(2) The resource productivity level reached during the twin transformation (positive).

The level of resource productivity measures the resource efficiency in the context of the digital and sustainable transitions. The positive impact means that SMEs optimize resources, reduce waste, and increase productivity.

(3) The market share gained for selling products produced using technologies that are friendly to the environment (positive).

This criterion measures the success of small- and medium-sized enterprises in the market to sell products that have been manufactured using environmentally friendly technologies. The increase in market share reflects the valorization of consumers, the levels of competitiveness, and a positive environmental impact.

(4) The initial investment (negative).

The initial investments needed to achieve the digital and sustainable transition, particularly for SMEs with limited financial resources, can be a major obstacle. An increased initial investment can be a challenge in implementing sustainable practices.

(5) The technical complexity (negative).

Technical complexity leads to challenges related to integrating and managing new digital technologies. Increased technical complexity can lead to implementation difficulties, disruptions, and operational risks.

(6) The number of digital and sustainable technologies used by SMEs (positive).

This criterion assesses the diversity of digital and sustainable technologies used by SMEs. A larger number means more complex and efficient changes that will bring greater benefits in various business areas.

Developing an SME impact assessment system will allow stakeholders to systematically assess and prioritize SMEs, considering their performance in digital and sustainable transitions. It provides a structured approach to policymakers for understanding the holistic impact of these changes, allowing them to make informed decisions about support, investment, and other development initiatives.

The framework will consist four steps:

1. The calculation of weights for the factors;
2. The revision of the consistency of experts' judgments;
3. The normalization of the values of the factors;
4. The formation of priority sequence.

The application of the multi-criteria decision-making method depends on the calculation of criteria weights. Assign weight to each criterion according to its relative importance. If market success and large-scale take-up were important objectives, this could be further hampered, for example, by the market share achieved and changes in the number of SMEs. Multiply the standard ratings by these weights and calculate the weighted number of each SME. This provides consolidated metrics that reflect the overall performance across all conditions.

Experts are usually used for the estimation of weights. In case studies, a minimum number of seven experts has to be used. To construct the framework, SME and ICT sector experts were invited for the ranking of the criteria.

The concordance coefficient is calculated for the consistency of the experts' judgments (for more details, see Appendix A). Perform a sensitivity analysis to understand the effect of changes in body weight or assessment on the overall score. This helps to identify the factors that most affect and increase the stability of the decision-making process.

Assess each SME against each criterion, evaluating them based on their performance. The positive effects should be outweighed and the negative effects should be smaller.

Based on the COPRAS method, the multiple criteria problem is represented by a matrix. In our case, the matrix contains six factors (rows) and n alternatives (columns) (see Appendix B). For the convenience of the evaluators, it is recommended to present the calculation results in the form of a normalized value matrix, as is given in Appendix C. Normalize the results to ensure comparability of the conditions. This includes turning raw results into a common benchmark by promoting fair comparisons.

The formulated framework could rank the alternatives in the proper priority sequence. We get the final result—a priority sequence (rank for each alternative). For example, alternative A1 gets rank 3, A2—1, A3—2. SMEs are assessed based on their overall weighted performance. Advanced SMEs are expected to deliver positive results due to the digital and sustainable transitions.

The above-stated criteria could be evaluated by using firm managers or market experts, depending on the purpose of the framework application (see the example under Figure 7). The framework is used for the self-evaluation of the SMEs sector.

The developed framework could be applied to case studies looking for practical evidence. Its practical application has varying directions, depending on when the group or individual decision makers use it.

The above-proposed framework could be used to systematically assess the results achieved and minimize the market and policy challenges.

The provided framework shows which areas require more attention by SMEs and policy makers responding to the twin transformation objectives.

This framework could be used to further revise the country-based or sector-based progress via the benchmarking of the achievements with other countries and/or sectors.

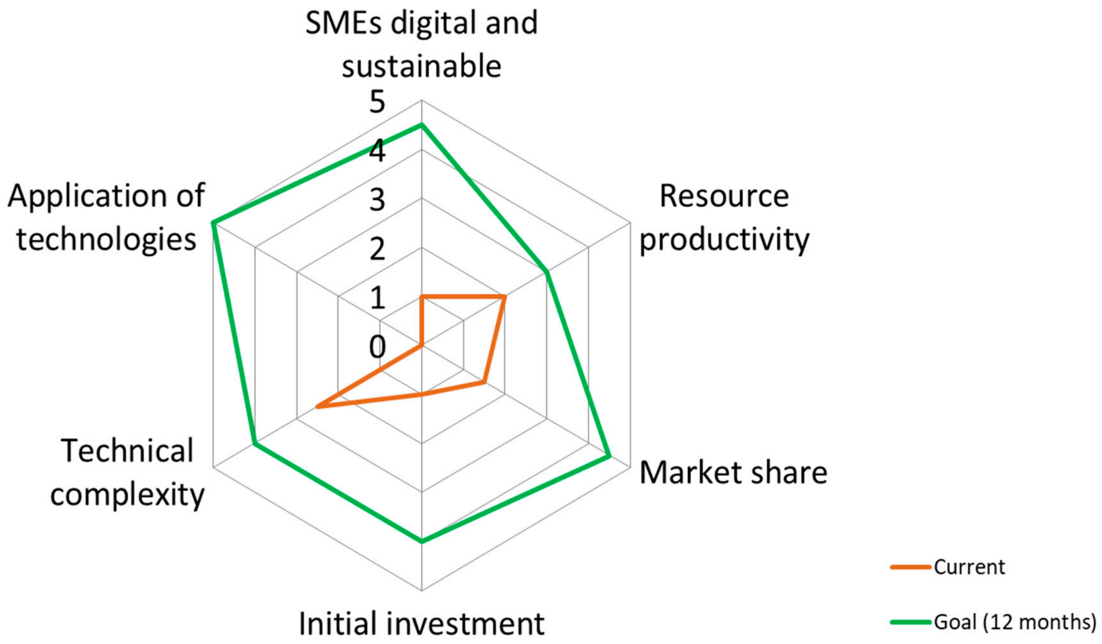

Figure 7. Multi-criteria decision making-based assessment framework. Here, 0 = not actual; 1 = no data to evaluate; 2 = just started; 3 = could be better; 4 = good; 5 = high achievements.

7. Discussions

The digital and sustainable transformations of SMEs requires up-to-date information on the latest developments in research. However, based on the general trends and challenges, there are some possible drawbacks in the research:

The results obtained from the conducted literature analysis reveals the need for more in-depth discussions of the importance of integrating digital and sustainable transformations, particularly in the context of European Union (EU) policies and the United Nations' sustainable development goals. This emphasizes the need for research and strategic initiatives in order to accelerate the digitization of small and medium enterprises (SMEs) in EU countries, with a focus on understanding the interplay between digital and green transitions. The European Commission's Green Deal is highlighted as a comprehensive strategy for achieving climate neutrality by 2050, but, until recently, digital transformation lacked a focus on sustainability, with a significant number of EU countries lacking the tools for SMEs to adapt to the sustainable requirements. The research emphasizes the limited attention given to SMEs in the context of digital and sustainable transformations, with a call for more comprehensive studies in this area. It also discusses the potential benefits of these transformations for SMEs, such as reducing environmental footprints through the implementation of digital solutions and sustainable practices. The research analysis revealed the importance of delving into different perspectives for a successful twin (digital and sustainable) transformation, including organizational change, resource utilization, user-friendly solutions, and gaining a competitive advantage. This suggests that SMEs can leverage their internal resources and capabilities in order to gain a competitive edge, adopt user-friendly solutions, and align their initiatives with both environmental and economic aspects.

Research can respond to the specific challenges SMEs face while considering digital and sustainable practices. By identifying the best practices, the authors ensure a smooth integration process.

The possibility of developing standardized performance parameters to assess the results of the digital and sustainable transformation of SMEs could be explored. The authors filled the research gap and suggested an assessment framework, including quantitative and qualitative indicators that reflect the diversity of these changes. The literature review shows a closer link between bibliometric map clusters and SME aspects, which may be needed to further explore the links between the twin transformation and SME concepts.

The paper identified the main factors that promote and postpone twin transformation. The authors named six factors, four of which are positive, such as the number of SMEs becoming digital and sustainable; the resource productivity level reached during the twin transformation, the market share gained for selling products produced using technologies that are friendly to the environment; the number of digital and sustainable technologies applied by SMEs. On the other hand, two of them are negative, such as the initial investment and technical complexities. The authors identified a research gap, which is the highest in Portugal, where SMEs overcome the bigger size of companies in terms of the progress and values of 18 statistical indicators. In addition, the authors created an assessment framework based on research results, helping measure SMEs' progress toward twin transformations.

The assessment of the long-term achievements of SMEs after the digital and sustainable transition could help increase SMEs' resilience to future challenges.

Researchers can make an important contribution in this field by filling these research gaps and providing valuable information to policymakers, practitioners, and researchers involved in the digital and sustainable transformation of SMEs. The paper fills research gaps and analyses the results of the twin transformation, which is evident among EU-27 SMEs in terms of speed. The paper suggests an assessment framework that helps to measure SME progress towards twin transformations. Furthermore, the country-based or sector-based factors could also be analyzed.

8. Practical Consequences

This document outlines how SMEs can influence the direction and speed of transformation. Policymakers could foster twin transformations in SMEs at a key stage, using different governmental levels in order to find support mechanisms. ICT sector enterprises need an effective exchange of information and a broad and transparent search for solutions, which may require adopting solutions for SMEs' needs and the mass spread of adjusted solutions in order to implement the critical mass of SMEs.

The study allows identifying the means necessary for twin transformations in SME development, such as the reduction of initial investments and technical complexities, which policymakers could apply to accelerate further progress.

Further research is needed to understand the specificities of sustainability and the twin transformation in the respective clusters. Further exploration of the links between digitalization and SMEs, particularly the lack of cluster fragmentation, could provide fertile ground for further research. For future studies, it would be interesting to research how SDGs are linked with SMEs to orient towards twin transformations.

9. Conclusions

The research covering twin transformations and the assessment of the EU SMEs is an important research area in management studies. Therefore, the analysis of changes in competitive business advantages resulting from twin transitions and the assessment of SMEs is quite new as a response to implementing Sustainable Development Goals and Green Deal initiatives.

Bibliometric analysis provides an overview of keyword relevance and the relationship between the different groups involved in the digital and sustainable transformation of SMEs. Bibliometric analysis results show that most links are evident under the first cluster. The second cluster demonstrates links between digitalization and sustainability. However, SME aspects are not covered under this frame. The third cluster shows that the literature explores where SMEs are facing a digital transition, but this may not be the most important aspect.

The statistical analysis shows that the most active SMEs in reaching some of indicators can be found in Portugal, Austria, and Finland; the most passive can be found in Hungary, Greece, and Bulgaria, as they lag behind in the frame of some indicators.

In this paper, the authors provided a standardized assessment framework that allows us to measure the performance of twin transformations in SMEs. Six factors identified during the literature review were included in the proposed framework, which uses the concept of Roger's innovation adoption curve in order to measure the number of SMEs that became digital and sustainable. The suggested framework could include quantitative and qualitative measures, following the practical assessment needs.

The presented framework highlights the specific areas that demand increased focus from SMEs and policymakers in addressing twin transformation objectives. It can be utilized to assess and enhance country-specific or sector-specific progress through benchmarking achievements against those of other countries and/or sectors.

The research has limitations as the study included six factors for the assessment framework; however, several other factors, such as government policy and regulation, could also be limit such research. Future research may address the role of government policies and initiatives in supporting or preventing the digital and sustainable transformations of SMEs. It would be useful to understand the impact of the regulatory framework on the adoption rates and strategies. However, the structural framework proposed in this paper for the systematic assessment of impacts and policy options on a wider scale is limited and could therefore be extended further, including more factors, for example.

For further bibliometric literature review studies, it could be useful to analyze the studies focusing on periods other than 2023.

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Appendix A. Calculation of Concordance Coefficient

The sum c of scores c_{ij}, presented by experts, is obtained using Equation (A1):

$$c = \sum_{e=1}^{r} c_{ie}\ (i = 1, \ldots, n) \tag{A1}$$

Here, n is the number of factors; r—is the number of experts (equal to 7); i—is the particular number of factors; e—is the particular expert.

$$q_i = \frac{c_i}{c},\ \sum_{i=1}^{6} q_i = 1 \tag{A2}$$

Here, q is the significance of factor (its weight), c_i—shows all scores for factor i.

The coefficient of concordance, named W, is obtained according to Equation (A3):

$$\begin{gathered} W = \frac{N}{N_{max}},\ \ when\ N = \sum_{i=1}^{n} (c_i - \bar{c})^2, \\ where\ \bar{c} = \frac{1}{2} r(n+1) = \frac{1}{2} \cdot 7(6+1) = 24.5 \end{gathered} \tag{A3}$$

Here, $\bar{c}$ is the overall average, N—is the sum of deviations, which shows the difference from the average squared, N_{max}—is the sum of deviations in the ideally agreed case, which is obtained using the Equation (A4).

The significance x^2 for the coefficient of concordance is obtained according to Equation (A5).

Random number x^2 is distributed under x^2 with the degrees of freedom v (then $\nu = n - 1$) of the chosen significance level α (in practice, α is usually equal to 0.05 or 0.01). The assessments of experts are aligned. The calculated x^2 value is greater than the x_{kr} (the x_{kr} value is taken from the distribution tables with $\nu = 6 - 1 = 5$ the degrees of freedom and significance level $\alpha = 0.05$ equal 11.07). If the significance equal to x^2 is greater than the critical value, this means it is equal to 11.07 when experts' judgments are in good agreement [93].

$$N_{\max} = \frac{r^2 n(n^2 - 1)}{12} = \frac{49 \cdot 6 \cdot (6^2 - 1)}{12} = 857.5 \quad \text{(A4)}$$

$$x^2 = Wr(n-1) = W \cdot 7 \cdot (6-1) = 35 \cdot W \quad \text{(A5)}$$

Appendix B. Formed Matrix

Factors			Alternatives					Sum of Values
Name	Direction	Weight	A1	A2	A3	…	An	
			Values for Each Factor					
C_1	Max	q_1	d_{11}	d_{12}	d_{13}	⋯	d_{1n}	$S_1 = \sum_{j=1}^{n} d_{1j}$
C_2	Max	q_2	d_{21}	d_{22}	d_{23}	⋯	d_{2n}	$S_2 = \sum_{j=1}^{n} d_{2j}$
C_3	Max	q_3	d_{31}	d_{32}	d_{33}	⋯	d_{3n}	$S_3 = \sum_{j=1}^{n} d_{3j}$
C_4	Min	q_4	d_{41}	d_{42}	d_{43}	⋯	d_{4n}	$S_4 = \sum_{j=1}^{n} d_{4j}$
C_5	Min	q_5	d_{51}	d_{52}	d_{53}	⋯	d_{5n}	$S_5 = \sum_{j=1}^{n} d_{5j}$
C_6	Max	q_6	d_{61}	d_{62}	d_{63}	⋯	d_{6n}	$S_6 = \sum_{j=1}^{n} d_{6j}$

Appendix C. Normalized Matrix

Alternatives	Factors						The Sum of Normalized Maximizing Factors	The Sum of Normalized Minimizing Factors	The Relative Importance of Comparable Variants
Name	C_1	C_2	C_3	C_4	C_5	C_6			
	Normalized Values								
A_1	D_{11}	D_{21}	D_{31}	D_{41}	D_{51}	D_{61}	S_{+1}	S_{-1}	Q_1
A_2	D_{12}	D_{22}	D_{32}	D_{42}	D_{52}	D_{62}	S_{+2}	S_{-2}	Q_2
A_3	D_{13}	D_{23}	D_{33}	D_{43}	D_{53}	D_{63}	S_{+3}	S_{-3}	Q_3
…	…	…	…	…	…	…	…	…	…
A_n	D_{1n}	D_{2n}	D_{3n}	D_{4n}	D_{5n}	D_{6n}	S_{+n}	S_{-n}	Q_n
Sum	D_{1j}	D_{2j}	D_{3j}	D_{4j}	D_{5j}	D_{6j}	$\sum_{i=1}^{6} \sum_{j=1}^{n} D_{ij} = S_+ + S_- = 1$		

Normalization is applied to avoid the difficulties causing different dimensions of six factors. Before normalization, the weights of factors are presented in the decision table. After this, the matrix is normalized according to the Equation (A6). The sum of normalized values equals one [94].

$$D_{ij} = \frac{d_{ij}q_i}{\sum_{j=1}^{n} d_{ij}},\ i = \overline{1,6};\ j = \overline{1,n},\ \ when \sum_{i=1}^{6}\sum_{j=1}^{n} D_{ij} = 1 \tag{A6}$$

Here, D_{ij} is the normalized value, d_{ij} is the value of the factor, i—is the factor value at the j alternative, and n—is the number of alternatives included in the comparison.

The following calculation of the alternative j is described by minimizing and maximizing the normalized indicator values.

In any case, the alternative and the sum are always equal to the maximize S_+ and minimize S_- criteria weight amounts, as specified in Equation (A7):

$$\begin{gathered} S_{+j} = \sum_{i=1}^{6} D_{+ij},\ j = \overline{1,n} \qquad S_{-j} = \sum_{i=1}^{6} D_{-ij},\ j = \overline{1,n} \\ S_{+} = \sum_{j=1}^{n} S_{+j} = \sum_{i=1}^{6}\sum_{j=1}^{n} D_{+ij} \end{gathered} \tag{A7}$$

The alternatives are described by considering the lowest minimizing value. The relative importance of alternatives is obtained by using the Equation (A8):

$$Q_j = S_{+j} + \frac{S_{-min}\cdot\sum_{j=1}^{n} S_{-j}}{S_{-j}\cdot\sum_{j=1}^{n}\frac{S_{-min}}{S_{-j}}},\ j = \overline{1,n} \tag{A8}$$

Finally, the priority sequence is defined as $Q_1 > Q_2 > Q_3$. This means the greater the number is for Q_j, the higher priority is.

Appendix D. The List of Abbreviations

EU	The European Union
SME	Small and medium-sized enterprise
ICT	Information and communication technologies
DII	Digital intensity index
twin	Digital and sustainable
SD	Sustainable Development
SDG	Sustainable Development Goals
AHP	Analytical Hierarchy Process
COPRAS	Complex Proportion Assessment
DEMATEL	Comprehensive method for building and analysing a structural model involving causal relationships among complex factors
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
CO_2	Carbon dioxide

References

1. Jöhnk, J.; Ollig, P.; Oesterle, S.; Riedel, L.N. The Complexity of Digital Transformation-Conceptualizing Multiple Concurrent Initiatives. In *Wirtschaftsinformatik (Zentrale Tracks)*; Fraunhofer Society: Munich, Germany, 2020; pp. 1051–1066.
2. Benedetti, I.; Guarini, G.; Laureti, T. Digitalization in Europe: A potential driver of energy efficiency for the twin transition policy strategy. *Socio-Econ. Plan. Sci.* **2023**, *89*, 101701. [CrossRef]
3. Beier, G.; Matthess, M.; Guan, T.; Grudzien, D.I.D.O.P.; Xue, B.; de Lima, E.P.; Chen, L. Impact of Industry 4.0 on corporate environmental sustainability: Comparing practitioners' perceptions from China, Brazil and Germany. *Sustain. Prod. Consum.* **2022**, *31*, 287–300. [CrossRef]
4. TWI2050—The World in 2050. In *Transformations to Achieve the Sustainable Development Goals*; Report Prepared by the World in 2050 Initiative; International Institute for Applied Systems Analysis (IIASA): Laxenburg, Austria, 2018; Available online: www.twi2050.org (accessed on 30 December 2023).

5. European Commission. *Communication from the Commission to the European Parliament and the Council 2022 Strategic Foresight Report Twinning the Green and Digital Transitions in the New Geopolitical Context COM/2022/289 Final*; European Commission: Brussels, Belgium, 2022.
6. European Commission. The European Green Deal. Striving to be the First Climate-Neutral Continent. 2024. Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (accessed on 30 December 2023).
7. Truong, T.C. The impact of digital transformation on environmental sustainability. *Adv. Multimed.* **2022**, *2022*, 6324325. [CrossRef]
8. Brodny, J.; Tutak, M. Digitalization of small and medium-sized enterprises and economic growth: Evidence for the EU-27 countries. *J. Open Innov. Technol. Mark. Complex.* **2022**, *8*, 67. [CrossRef]
9. Hanelt, A.; Bohnsack, R.; Marz, D.; Antunes Marante, C. A systematic review of the literature on digital transformation: Insights and implications for strategy and organizational change. *J. Manag. Stud.* **2021**, *58*, 1159–1197. [CrossRef]
10. Herczeg, B.; Pintér, É.; Bagó, P. How green and digital transformation shapes industries: Twin transition to a green and digital future. *Vez./Bp. Manag. Rev.* **2023**, *54*, 51–63. [CrossRef]
11. Lee, W.J.; Mwebaza, R. Digitalization to Achieve Technology Innovation in Climate Technology Transfer. *Sustainability* **2021**, *14*, 63. [CrossRef]
12. Chatzistamoulou, N.; Tyllianakis, E. Commitment of European SMEs to resource efficiency actions to achieve sustainability transition. A feasible reality or an elusive goal? *J. Environ. Manag.* **2022**, *321*, 115937. [CrossRef]
13. Hassoun, A.; Prieto, M.A.; Carpena, M.; Bouzembrak, Y.; Marvin, H.J.; Pallares, N.; Bono, G. Exploring the role of green and Industry 4.0 technologies in achieving sustainable development goals in food sectors. *Food Res. Int.* **2022**, *162*, 112068. [CrossRef]
14. Kim, G.Y.; Flores-García, E.; Wiktorsson, M.; Do Noh, S. Exploring economic, environmental, and social sustainability impact of digital twin-based services for smart production logistics. In *IFIP International Conference on Advances in Production Management Systems*; Springer International Publishing: Cham, Switzerland, 2021; pp. 20–27.
15. Delgosha, M.S.; Saheb, T.; Hajiheydari, N. Modelling the asymmetrical relationships between digitalisation and sustainable competitiveness: A cross-country configurational analysis. *Inf. Syst. Front.* **2021**, *23*, 1317–1337. [CrossRef]
16. Ogrean, C.; Herciu, M. Romania's SMEs on the Way to EU's Twin Transition to Digitalization and Sustainability. *Stud. Bus. Econ.* **2021**, *16*, 282–295. [CrossRef]
17. Pacciani, C. *Twin Transition Policies for a Sustainable Recovery: An SME Perspective*; Università Ca' Foscari Venezia: Venice, Italy, 2022.
18. Caro-González, A.; Serra, A.; Albala, X.; Borges, C.E.; Casado-Mansilla, D.; Colobrans, J.; Iñigo, E.; Millard, J.; Mugarra-Elorriaga, A.; Petrevska Nechkoska, R. The Three MuskEUteers: Pushing and Pursuing a "One for All, All for One" Triple Transition: Social, Green, and Digital. In *Facilitation in Complexity: From Creation to Co-creation, from Dreaming to Co-Dreaming, from Evolution to Co-Evolution*; Springer International Publishing: Cham, Switzerland, 2023; pp. 3–28.
19. Paiho, S.; Wessberg, N.; Dubovik, M.; Lavikka, R.; Naumer, S. Twin transition in the built environment–Policy mechanisms, technologies and market views from a cold climate perspective. *Sustain. Cities Soc.* **2023**, *98*, 104870. [CrossRef]
20. Peng, Y.; Ahmad, S.F.; Irshad, M.; Al-Razgan, M.; Ali, Y.A.; Awwad, E.M. Impact of digitalization on process optimization and decision-making towards sustainability: The moderating role of environmental regulation. *Sustainability* **2023**, *15*, 15156. [CrossRef]
21. Rao, P.; Verma, S.; Rao, A.A.; Joshi, R. A conceptual framework for identifying sustainable business practices of small and medium enterprises. *Benchmarking Int. J.* **2023**, *30*, 1806–1831. [CrossRef]
22. Sabaityte, J.; Meidute-Kavaliauskiene, I.; Zinkevičiūte, V.; Vasiliauskas, A.V. Framework for electronic business development as a prerequisite for top management to gain sustainable competitive advantage. *Int. J. Learn. Chang.* **2022**, *14*, 625–645. [CrossRef]
23. Gao, S.; Ma, X.; Zhao, X. Entrepreneurship, Digital Capabilities, and Sustainable Business Model Innovation: A Case Study. *Mob. Inf. Syst.* **2022**, *2022*, 5822423. [CrossRef]
24. Bednarčíková, D.; Repiská, R. Digital transformation in the context of the European Union and the use of digital technologies as a tool for business sustainability. In *SHS Web of Conferences*; EDP Sciences: Les Ulis, France, 2021; Volume 115, p. 01001.
25. Lee, C.C.; He, Z.W.; Yuan, Z. A pathway to sustainable development: Digitization and green productivity. *Energy Econ.* **2023**, *124*, 106772. [CrossRef]
26. Luo, S.; Yimamu, N.; Li, Y.; Wu, H.; Irfan, M.; Hao, Y. Digitalization and sustainable development: How could digital economy development improve green innovation in China? *Bus. Strategy Environ.* **2023**, *32*, 1847–1871. [CrossRef]
27. Schneider, S. The impacts of digital technologies on innovating for sustainability. In *Innovation for Sustainability Business Transformations towards a Better World*; Springer: Berlin/Heidelberg, Germany, 2019; pp. 415–433.
28. Chen, X.; Despeisse, M.; Johansson, B. Environmental sustainability of digitalization in manufacturing: A review. *Sustainability* **2020**, *12*, 10298. [CrossRef]
29. Girrbach, P. Digitalization and its Contribution to Sustainability in Terms of the Social Dimension. In *Innovation Management, Entrepreneurship and Sustainability (IMES 2018)*; Vysoká škola ekonomická v Praze: Praha, Žižkov, 2018; pp. 369–379.
30. Brenner, B.; Hartl, B. The perceived relationship between digitalization and ecological, economic, and social sustainability. *J. Clean. Prod.* **2021**, *315*, 128128. [CrossRef]
31. Niehoff, S. Aligning digitalisation and sustainable development? Evidence from the analysis of worldviews in sustainability reports. *Bus. Strategy Environ.* **2022**, *31*, 2546–2567. [CrossRef]

32. Kapidani, N.; Bauk, S.; Davidson, I.E. Digitalization in developing maritime business environments towards ensuring sustainability. *Sustainability* **2020**, *12*, 9235. [CrossRef]
33. Schoormann, T.; Behrens, D.; Knackstedt, R. Design principles for leveraging sustainability in business modelling tools. *Res. Prog. Pap.* **2018**, *71*, 1–13.
34. Irimiás, A.; Mitev, A. Change management, digital maturity, and green development: Are successful firms leveraging on sustainability? *Sustainability* **2020**, *12*, 4019. [CrossRef]
35. Bouwman, H.; De Reuver, M.; Heikkilä, M.; Fielt, E. Business model tooling: Where research and practice meet. *Electron. Mark.* **2020**, *30*, 413–419. [CrossRef]
36. Hänninen, M.; Smedlund, A.; Mitronen, L. Digitalization in retailing: Multi-sided platforms as drivers of industry transformation. *Balt. J. Manag.* **2018**, *13*, 152–168. [CrossRef]
37. Langley, D.J. Digital product-service systems: The role of data in the transition to servitization business models. *Sustainability* **2022**, *14*, 1303. [CrossRef]
38. Kotarba, M. Digital transformation of business models. *Found. Manag.* **2018**, *10*, 123–142. [CrossRef]
39. Bocken, N.; Boons, F.; Baldassarre, B. Sustainable business model experimentation by understanding ecologies of business models. *J. Clean. Prod.* **2019**, *208*, 1498–1512. [CrossRef]
40. Evans, J.; Karvonen, A.; Luque-Ayala, A.; Martin, C.; McCormick, K.; Raven, R.; Palgan, Y.V. Smart and sustainable cities? Pipedreams, practicalities and possibilities. *Local Environ.* **2019**, *24*, 557–564. [CrossRef]
41. Müller, J.J.E.C. *Enabling Technologies for Industry 5.0*; European Commission: Brussels, Belgium, 2020; pp. 8–10.
42. Wuest, T.; Romero, D.; Khan, M.A.; Mittal, S. The triple bottom line of smart manufacturing technologies: An economic, environmental, and social perspective. In *Handbook of Smart Technologies: An Economic and Social Perspective*; Routledge: London, UK, 2022; pp. 310–330. Available online: https://www.taylorfrancis.com/chapters/edit/10.4324/9780429351921-20 (accessed on 20 November 2023).
43. Isensee, C.; Teuteberg, F.; Griese, K.M.; Topi, C. The relationship between organizational culture, sustainability, and digitalization in SMEs: A systematic review. *J. Clean. Prod.* **2020**, *275*, 122944. [CrossRef]
44. Busse, R.; Doganer, U. The role of compliance for organisational change: Qualitative evidence from German SMEs. *J. Organ. Chang. Manag.* **2018**, *31*, 334–351. [CrossRef]
45. Kääriäinen, J.; Pussinen, P.; Saari, L.; Kuusisto, O. Applying the positioning phase of the digital transformation model in practice for SMEs: Toward systematic development of digitalization. *Int. J. Inf. Syst. Proj. Manag.* **2020**, *8*, 24–43. [CrossRef]
46. Tuukkanen, V.; Wolgsjö, E.; Rusu, L. Cultural values in digital transformation in a small company. *Procedia Comput. Sci.* **2022**, *196*, 3–12. [CrossRef]
47. Li, L.; Su, F.; Zhang, W.; Mao, J.Y. Digital transformation by SME entrepreneurs: A capability perspective. *Inf. Syst. J.* **2018**, *28*, 1129–1157. [CrossRef]
48. Jeansson, J.; Bredmar, K. Digital transformation of SMEs: Capturing complexity. In Proceedings of the 32nd Bled EConference Humanizing Technology for a Sustainable Society, Bled, Slovenia, 16–19 June 2019.
49. Baia, E.; Ferreira, J.J.; Rodrigues, R. Value and rareness of resources and capabilities as sources of competitive advantage and superior performance. *Knowl. Manag. Res. Pract.* **2020**, *18*, 249–262. [CrossRef]
50. Civelek, M.; Krajčík, V.; Ključnikov, A. The impacts of dynamic capabilities on SMEs' digital transformation process: The resource-based view perspective. *Oeconomia Copernic.* **2023**, *14*, 1367–1392. [CrossRef]
51. Zhang, X.; Xu, Y.; Ma, L. Research on successful factors and influencing mechanism of the digital transformation in SMEs. *Sustainability* **2022**, *14*, 2549. [CrossRef]
52. Chumphong, O.; Srimai, S.; Potipiroon, W. The resource-based view, dynamic capabilities and SME performance for SMEs to become smart enterprises. *ABAC ODI J. Vis. Action Outcome* **2020**, *7*, 129.
53. Rehman, S.U.; Giordino, D.; Zhang, Q.; Alam, G.M. Twin transitions & industry 4.0: Unpacking the relationship between digital and green factors to determine green competitive advantage. *Technol. Soc.* **2023**, *73*, 102227.
54. Reinhartz-Berger, I.; Hartman, A.; Kliger, D. Adoption of IT solutions: A data-driven analysis approach. *Inf. Syst.* **2024**, *120*, 102313. [CrossRef]
55. Liu, Z.; Han, S.; Yao, M.; Gupta, S.; Laguir, I. Exploring drivers of eco-innovation in manufacturing firms' circular economy transition: An awareness, motivation, capability perspective. *Ann. Oper. Res.* **2023**, 1–36. [CrossRef]
56. Hu, D.; Lin, M.; Feng, S.; Yi, G. How does digital transformation affect environmental service enterprises'performance? the main sources and internal mechanisms. *Int. J. Innov. Manag.* **2023**, *27*, 2350028. [CrossRef]
57. Montresor, S.; Vezzani, A. Digital technologies and eco-innovation. Evidence of the twin transition from Italian firms. *Ind. Innov.* **2023**, *30*, 766–800. [CrossRef]
58. Marchegiani, L. *Digital Transformation and Knowledge Management*; Routledge: London, UK, 2021.
59. Chatzistamoulou, N. Is digital transformation the Deus ex Machina towards sustainability transition of the European SMEs? *Ecol. Econ.* **2023**, *206*, 107739. [CrossRef]
60. Dossou, P.E.; Laouénan, G.; Didier, J.Y. Development of a sustainable industry 4.0 approach for increasing the performance of SMEs. *Processes* **2022**, *10*, 1092. [CrossRef]
61. Khan, I.S.; Ahmad, M.O.; Majava, J. Industry 4.0 and sustainable development: A systematic mapping of triple bottom line, Circular Economy and Sustainable Business Models perspectives. *J. Clean. Prod.* **2021**, *297*, 126655. [CrossRef]

62. Rehman, F.U.; Gyamfi, S.; Rasool, S.F.; Akbar, F.; Hussain, K.; Prokop, V. The nexus between circular economy innovation, market competitiveness, and triple bottom lines efficiencies among SMEs: Evidence from emerging economies. *Environ. Sci. Pollut. Res.* **2023**, *30*, 122274–122292. [CrossRef]
63. Qi, X.; Yang, Z. Drivers of green innovation in BRICS countries: Exploring tripple bottom line theory. *Econ. Res.-Ekon. Istraživanja* **2023**, *36*, 2150670. [CrossRef]
64. Ortega-Gras, J.J.; Bueno-Delgado, M.V.; Cañavate-Cruzado, G.; Garrido-Lova, J. Twin transition through the implementation of industry 4.0 technologies: Desk-research analysis and practical use cases in Europe. *Sustainability* **2021**, *13*, 13601. [CrossRef]
65. Van Eck, N.J.; Waltman, L.; Dekker, R.; Van Den Berg, J. A comparison of two techniques for bibliometric mapping: Multidimensional scaling and VOS. *J. Am. Soc. Inf. Sci. Technol.* **2010**, *61*, 2405–2416. [CrossRef]
66. Waltman, L.; Van Eck, N.J.; Noyons, E.C. A unified approach to mapping and clustering of bibliometric networks. *J. Informetr.* **2010**, *4*, 629–635. [CrossRef]
67. Waltman, L.; Van Eck, N.J. A smart local moving algorithm for large-scale modularity-based community detection. *Eur. Phys. J. B* **2013**, *86*, 471. [CrossRef]
68. Sousa, N.; Alén, E.; Losada, N.; Melo, M. Virtual Reality in Tourism Promotion: A Research Agenda Based on A Bibliometric Approach. *J. Qual. Assur. Hosp. Tour.* **2022**, *25*, 313–342. [CrossRef]
69. Vide, R.K.; Hunjet, A.; Kozina, G. Enhancing Sustainable Business by SMEs' Digitalization. *J. Strateg. Innov. Sustain.* **2022**, *17*, 13–22.
70. Bianchini, S.; Damioli, G.; Ghisetti, C. The environmental effects of the "twin" green and digital transition in European regions. *Environ. Resour. Econ.* **2023**, *84*, 877–918. [CrossRef] [PubMed]
71. Song, M.; Peng, L.; Shang, Y.; Zhao, X. Green technology progress and total factor productivity of resource-based enterprises: A perspective of technical compensation of environmental regulation. *Technol. Forecast. Soc. Chang.* **2022**, *174*, 121276. [CrossRef]
72. Brunetti, F.; Matt, D.T.; Bonfanti, A.; De Longhi, A.; Pedrini, G.; Orzes, G. Digital transformation challenges: Strategies emerging from a multi-stakeholder approach. *TQM J.* **2020**, *32*, 697–724. [CrossRef]
73. Janssen, M.; Weerakkody, V.; Ismagilova, E.; Sivarajah, U.; Irani, Z. A framework for analysing blockchain technology adoption: Integrating institutional, market and technical factors. *Int. J. Inf. Manag.* **2020**, *50*, 302–309. [CrossRef]
74. Teng, X.; Wu, Z.; Yang, F. Research on the relationship between digital transformation and performance of SMEs. *Sustainability* **2022**, *14*, 6012. [CrossRef]
75. Eurostat. How Digitalised Are the EU's Enterprises. 2023. Available online: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220826-1 (accessed on 10 November 2023).
76. Burinskienė, A.; Seržantė, M. Digitalisation as the Indicator of the Evidence of Sustainability in the European Union. *Sustainability* **2022**, *14*, 8371. [CrossRef]
77. Yin, S.; Zhang, N.; Ullah, K.; Gao, S. Enhancing digital innovation for the sustainable transformation of manufacturing industry: A pressure-state-response system framework to perceptions of digital green innovation and its performance for green and intelligent manufacturing. *Systems* **2022**, *10*, 72. [CrossRef]
78. Spaltini, M.; Poletti, A.; Acerbi, F.; Taisch, M. A quantitative framework for Industry 4.0 enabled Circular Economy. *Procedia CIRP* **2021**, *98*, 115–120. [CrossRef]
79. Arranz, C.F.; Arroyabe, M.F.; Arranz, N.; de Arroyabe, J.C.F. Digitalisation dynamics in SMEs: An approach from systems dynamics and artificial intelligence. *Technol. Forecast. Soc. Chang.* **2023**, *196*, 122880. [CrossRef]
80. Mubarak, M.F.; Shaikh, F.A.; Mubarik, M.; Samo, K.A.; Mastoi, S. The impact of digital transformation on business performance: A study of Pakistani SMEs. *Eng. Technol. Appl. Sci. Res.* **2019**, *9*, 5056–5061. [CrossRef]
81. El Hilali, W.; El Manouar, A.; Idrissi, M.A.J. Reaching sustainability during a digital transformation: A PLS approach. *Int. J. Innov. Sci.* **2020**, *12*, 52–79. [CrossRef]
82. Kim, S.S. Sustainable growth variables by industry sectors and their influence on changes in business models of SMEs in the era of digital transformation. *Sustainability* **2021**, *13*, 7114. [CrossRef]
83. Morozko, N.; Morozko, N.; Didenko, V. Applying the Theory of Fuzzy Logic in the Financial Management of Small Companies. *Montenegrin J. Econ.* **2022**, *18*, 49–60. [CrossRef]
84. Jomthanachai, S.; Rattanamanee, W.; Sinthavalai, R.; Wong, W.P. The application of genetic algorithm and data analytics for total resource management at the firm level. *Resour. Conserv. Recycl.* **2020**, *161*, 104985. [CrossRef]
85. Lacurezeanu, R.; Chis, A.; Bresfelean, V.P. Integrated Management Solution for a Sustainable SME—Selection Proposal Using AHP. *Sustainability* **2021**, *13*, 10616. [CrossRef]
86. Sriram, R.M.; Vinodh, S. Analysis of readiness factors for Industry 4.0 implementation in SMEs using COPRAS. *Int. J. Qual. Reliab. Manag.* **2021**, *38*, 1178–1192. [CrossRef]
87. Kumar, R.; Rehman, U.U.; Phanden, R.K. Strengthening the social performance of Indian SMEs in the digital era: A fuzzy DEMATEL analysis of enablers. *TQM J.* **2022**, *36*, 139–160. [CrossRef]
88. Nichifor, E.; Lixăndroiu, R.C.; Sumedrea, S.; Chițu, I.B.; Brătucu, G. How can SMEs become more sustainable? Modelling the m-commerce consumer behaviour with contingent free shipping and customer journey's touchpoints optimisation. *Sustainability* **2021**, *13*, 6845. [CrossRef]

89. Petani, F.J.; Zaoui, I.; Kovalev, S.; Montagnon, P. What will (and should) sustainable digital maturity look like in business ecosystems? A Delphi study on the best practices, barriers and regulation of digital transformation. *Int. J. Entrep. Small Bus.* **2023**, *49*, 87–122. [CrossRef]
90. Sassanelli, C.; Terzi, S. The D-BEST reference model: A flexible and sustainable support for the digital transformation of small and medium enterprises. *Glob. J. Flex. Syst. Manag.* **2022**, *23*, 345–370. [CrossRef]
91. Ardito, L.; Raby, S.; Albino, V.; Bertoldi, B. The duality of digital and environmental orientations in the context of SMEs: Implications for innovation performance. *J. Bus. Res.* **2021**, *123*, 44–56. [CrossRef]
92. Goerzig, D.; Bauernhansl, T. Enterprise architectures for the digital transformation in small and medium-sized enterprises. *Procedia CIRP* **2018**, *67*, 540–545. [CrossRef]
93. Podvezko, V. Agreement of expert estimates. *Technol. Econ. Dev. Econ.* **2005**, *2*, 101–107. [CrossRef]
94. Turskis, Z.; Zavadskas, E.K.; Peldschus, F. Multi-criteria optimization system for decision making in construction design and management. *Eng. Econ.* **2009**, *1*, 7–17.